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Risk Perception Regarding Energy Production: Factor Structure in a French Sample

Abstract
[Excerpt] "Considering that energy production is a key factor in the development of nations, it is important to have detailed information on the risks attributed by lay people to the different types of energy as well as the different stages of energy production. This study reports on the structure of risk perception with regard to energy production found among French participants. There have already been many investigations of risk perception related to energy production. . . .

The present study is a direct extension of the Mullet study. A similar, although more complete, set of items was used. These items related to specific energy domains as well as specific aspects of the energy production process. As in the Mullet study, nine energy sources (covering all currently known energy sources), were considered in this study: Wood and bio-mass, coal, gas, oil, nuclear, water, wind, geothermal, and solar. Also, nine stages in the energy production and utilization process were considered: obtaining raw materials, storage of raw materials, transportation of raw materials, energy production, waste products related to energy production, transportation of energy, transportation of waste products, the storage of waste products, and utilization of energy. Crossover of production phases and energy types resulted in a large number of items."

Keywords
risk, energy production

Risk Perception Regarding Energy Production: Factor Structure in a French Sample[*]

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"People respond to hazards according to their perceptions of the risks they pose. What they perceive, why they perceive it that way, and how they will subsequently behave is a matter of great import to industries and governments trying to assess and implement new technologies."[1] Considering that energy production is a key factor in the development of nations, it is important to have detailed information on the risks attributed by lay people to the different types of energy as well as the different stages of energy production. This study reports on the structure of risk perception with regard to energy production found among French participants.

There have already been many investigations of risk perception related to energy production. The majority can be classified into three categories. The first involves studies covering a wide sample of risks, with risks related to energy production being only a sub-sample. One main objective of these studies (initiated by Slovic, Fischhoff, and Lichtenstein's work[2]) has been to establish a hierarchy of risks, ranging from those rated as the most serious to those rated as being relatively innocuous; as well as determining how these perceptions differ according to the participant's gender,[3] person-

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[1] Ellen Peters & Paul Slovic, *The Role of Affect and Worldviews as Orienting Dispositions in the Perception and Acceptance of Nuclear Power*, 26 J. of Applied Soc. Psychol. 1427 (1996).

[2] Paul Slovic et al., *Characterizing Perceived Risk* in, *Perilous Progress*: *Managing the Hazards of Technology* 91-125 (R. Kates, C. Hohenemser, & R. Kasperson eds., Westview Press 1985).

[3] Cécilia Karpowicz-Lazreg & Etienne Mullet, *Societal Risks as Seen by a French Public*, 13 Risk Analysis 253 (1993).

ality,[4] social background,[5] cultural background,[6] and finally their area of occupational specialization.[7] Table 1 summarizes the various findings emerging from these studies. Generally, with the exception of three studies, ratings in the Nuclear power (or Nuclear waste) column were the highest, and in particular, higher than ratings in the Coal/Oil Plants column. Motor vehicles were the second highest risk. Risks associated with motor vehicles included both risks related to energy production (emission of carbon monoxide and lead into the atmosphere) as well as risks related to the transportation of passengers (accidents). The third position was occupied by the liquid natural gas and power lines items followed by the coal/oil power plant item. Ratings recorded for other items were generally lower.

Table 1

Mean Magnitude of Perceived Risk of Ten Hazards Linked to Energy Production, across 24 Studies, from 1985 to 2001.

Study (country, respondents, type of response scale)	Nucl. Power	Nucl. Waste	Motor Vehic.	Nat. Gas	Dams	Hydr. Power	H. Gas Furn.	Coal/ Oil pl.	Power Lines	Solar Energ.
Slovic et al., 1985 (USA, 175 students, 0-100 scale)	71.5		54.8	50.0	31.4	30.0	29.3	25.9		
Englander et al., 1986 (Hungary, 90 students, 0-100 scale)	31.6		47.9	29.8	17.3	27.8	24.3	35.4		
Teigen, Brun, and Slovic, 1988 (Norway, 35 students, 0-100 scale)	46.8		35.5	27.9	16.8	12.1	17.9	18.4		

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[4] Muriel Bouyer et al., *Personality Correlates of Risk Perception*, 21 Risk Analysis 457 (2001).

[5] *See supra* n. 2.

[6] Tornswald Englander et al., *A Comparative Analysis of Risk Perception in Hungary and the United States*, 1 Social Behavior 55 (1986); Daboula Koné & Etienne Mullet, *Societal Risk Perception and Media Coverage*, 14 Risk Analysis 21 (1994); Félix Neto & Etienne Mullet, *Societal Risk Perception by the Portuguese Public*, 50 European Rev. of Applied Psychol. 155 (2000).

[7] Bernd Rohrmann, *Risk Perception of Different Societal Groups: Australian Findings and Cross National Comparisons*, 46 Australian J. of Psychol. 150 (1994).

Table 1 (Cont'd.)

Study(country, respondents, type of response scale)	Nucl. Power	Nucl. Waste	Motor Vehic.	Nat. Gas	Dams	Hydr. Power	H. Gas Furn.	Coal/ Oil pl.	Power Lines	Solar Energ.
Keown, 1989 (Hong Kong, 65 students, 0-100 scale)	68.0		63.0					38.0		
Bastide et al., 1989 (France, 1000 persons, representative sample, % of resp. "very dangerous")	63%		52%		22%					
Mechitov and Rebrik, 1990 (USSR, 24 research associates, 0-100 scale)			14.8	13.8	9.7			27.1		
Goszczynska, Tyszka, and Slovic, 1991 (Poland, 140 professionals, 0-100 scale)	49.3		43.1			20.5		31.9		
Karpowicz Lazreg and Mullet, 1993 (France, 107 students, 0-100 scale)	68.6		44.8	43.2	31.6	34.7	32.5	27.7		25.2
Flynn, Slovic, and Mertz, 1994 (USA, 1512 persons, representative sample, 1-4 point scale)	2.90	3.40						2.80	2.60	
Koné and Mullet, 1994 (Burkina Faso, 51 persons, 0-100 scale)	77.9		39.1	49.5	34.7	43.6	38.6	34.9		37.2
Nyland, 1994 (Brazil, students and adults, 0-100 scale)	66.4		63.8	55.6	40.4	24.4	25.0	45.6		
Nyland, 1994 (Sweden, students and adults, 0-100 scale)	34.5		38.0	28.5	17.2	5.7	7.1	32.0		
Alhakami and Slovic, 1994 (USA, 100 students, 1-7 point scale)	4.58		5.74	4.89		2.52		4.74		1.68
MacGregor, Slovic, and Morgan, 1994 (USA, 60 adults, 1-7 point scale)	5.88				2.81				4.33	
Rohrmann, 1994 (Germany, 224 students and professionals, 0-10 scale)	6.10							5.60		

Table 1 (Cont'd.)

Study (country, respondents, type of response scale)	Nucl. Power	Nucl. Waste	Motor Vehicle	Nat. Gas	Dams	Hydr. Power	H. Gas furn.	Coal/ Oil pl.	Power Lines	Solar Energ.
Rohrmann, 1994 (Australia, 339 students and professionals, 0-10 scale)	7.00							5.10		
Rohrmann, 1994 (New Zealand, 278 students and professionals, 0-10 scale)	7.00							4.30		
Poumadère et al., 1995 (France, 1500 persons, % of resp. "very dangerous")	32%	71%						7%	18%	
Poumadère et al., 1995 (USA, 1500 persons, % of resp. "very dangerous")	33%	59%						16%	22%	
McDaniels, Axelrod, and Slovic, 1995 (USA, 68 students, -3/+3 scale)	1.57		1.28		0.86					
Wiegman et al., 1995 (France, 86 scientists, 1-7 scale)	4.20							2.20		
Wiegman et al., 1995 (Netherlands, 101 scientists, 1-7 scale)	3.60							2.70		
Finucane and Maybery, 1996 (Australia, 40 students, ranking)	5.00		2.00					9.00		
Savadori, Rumiati and Bonini, 1998 (Italy, 258 students and experts, 0-100 scale)	62.5		49.9					42.1		
Hermand, Mullet and Romptaux, 1998 (France, 32 persons aged 25, 0-100 scale)	71.3		29.4	28.8	15.9	14.7	29.4	45.6		25.0
Neto and Mullet, 2000 (Portugal, 99 students, 0-100 scale)	67.4		50.9	39.6	28.5	34.3	47.9	30.4		27.9
Neto and Mullet, 2000 (Macao, 101 students, 0-100 scale)	65.8		56.3	56.7	36.1	39.0	56.7	40.0		

Table 1 (Cont'd.)

Study (country, respondents, type of response scale)	Nucl. Power	Nucl. Waste	Motor Vehicle	Nat. Gas	Dams	Hydr. Power	H. Gas Furn.	Coal/ Oil pl.	Power Lines	Solar Energ.
Bouyer, Bagdassarian, Chaabane & Mullet, 2001 (France, 363 students and adults, 0-10 scale)	7.29	8.81		4.72	3.74	3.92	4.81	4.27	5.67	2.64
Mullet et al., 2003, (Finland, 125 students, 0-100 scale)	47.0		38.8	26.9	14.0	15.3	24.0	22.1		

The second category includes studies devoted to a specific type of energy or a specific phase in the energy production process. Nuclear energy is the energy field evaluated by the largest number of studies,[8] and more particularly, the storage of nuclear waste[9] as well as nuclear waste transportation aspects. [10] The second most important area would appear to con-

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[8] *See supra* n. 1; Dennis Showers & Robert Shrigley, *Effects of Knowledge and Persuasion on High-School Students' Attitudes toward Nuclear Power Plants*, 32 J. of Research in Sci. Teaching 29 (1995); Oene Wiegman et al., *Perception of Nuclear Energy and Coal in France and the Netherlands*, 15 Risk Analysis 513 (1995).

[9] Gilbert W. Basset et al., *On-Site Storage of High Level Nuclear Waste: Attitudes and Perceptions of Local Residents*, 16 Risk Analysis 309 (1996); Anders Biel & Ulf Dahlstrand, *Risk Perception and the Location of a Repository for Spent Nuclear Fuel*, 36 Scandinavian J. of Psychol. 25 (1995); Britt-Marie Drottz-Sjöberg & Lennart Sjöberg, *Adolescents' Attitudes to Nuclear Power and Radioactive Wastes*, 21 J. of Applied Soc. Psychol. 2007 (1991); Doug Easterling, *The Vulnerability of the Nevada Visitor Economy to a Repository at Yucca Mountain*, 17 Risk Analysis 635 (1997); James Flynn et al., *Trust as a Determinant of Opposition to a High-Level Radioactive Waste Repository: Analysis of a Structural Model*, 12 Risk Analysis 417 (1992); James Flynn et al., *Risk, Media, and Stigma at Rocky Flats*, 18 Risk Analysis 715 (1998); James Flynn et al. *Decidedly Different: Expert and Public Views of Risks from a Radioactive Waste Repository*, 13 Risk Analysis 643 (1993); Hank Jenkins-Smith & Gilbert W. Basset, *Perceived Risk and Uncertainty of Nuclear Waste: Differences among Science, Business, and Environmental Group Members*, 14 Risk Analysis 851 (1994); Howard Kunreuther et al., *Nevada's Predicament: Public Perceptions of Risk from the Proposed Nuclear Waste* Repository, 30 Environment 16 (1988); Paul Slovic et al., *Images of a Place and Vacation Preferences: Implications of the 1989 Surveys for Assessing the Economic Impacts of a Nuclear Waste Repository in Nevada*, Carson City, NV: Nevada Agency for Nuclear Projects (1990); Paul Slovic et al., *What Comes to Mind When You Hear the Words "Nuclear Waste Repository"? A study of 10,000 Images*, Carson City, NV: Nevada Agency for Nuclear Projects (1990); Paul Slovic et al., *Perceived Risk, Stigma, and Potential Economic Impacts of a High-Level Nuclear Waste Repository in Nevada*, 11 Risk Analysis 683 (1991); Anna Vari et al., *Public Concern about LLRW Facility Sitting: A Comparative Study*, 22 J. of Cross-Cultural Psychol. 83 (1991).

[10] Karl Larsen, *The Transportation of Nuclear Waste: Opinions and Attitudes in the Transportation Corridor and Metropolitan Portland*, 42 Intl. J. of Env. Stud. 123 (1992); Donald MacGregor et al., *Perceived Risk of Radioactive Waste Transportation through Oregon: Results of a Statewide Survey*, 14 Risk Analysis 5 (1994); Craig Summers & Donald W. Hine, *Nuclear Waste Goes on the Road: Risk Perception and Compensatory Tradeoffs in Single-Industry Communities*, 29 Canadian J. of Behavioral Sci. 210 (1997).

cern power transmission lines.[11] Recent work has also concerned oil spills.[12]

The third category of studies concerns the structure of risk perception.[13] These studies have shown that a simple three or four-axis system could satisfactorily account for the perception of societal risks. In this structure, an item such as nuclear power is powerfully saturated by a factor generally named Common-Dread, in contrast to an item such as non-nuclear electric power.

To the best of our knowledge, there has only been one overall study devoted to risk perception concerning energy production. In the study performed by Mullet et al.,[14] [hereinafter Mullet study], Belgian and French students assessed the overall risk magnitude (for health and environment) of 107 items relating to specific energy domains (wood and bio-mass, coal, gas, oil, nuclear, water, wind, geothermal, and solar) and specific aspects of the energy production process (obtaining raw materials, storage of raw materials, transportation of raw materials, energy production, waste products related to energy production, transportation of energy, transportation of waste products, the storage of waste products, and utilization of energy).

Concerning energy domains, nuclear energy received the highest ratings, almost regardless of the aspect of the energy production process considered (from the extraction of raw materials to the storage of production wastes); followed by oil with the second highest ratings. Gas occupies the third position, which was considered more risky than bio-mass and coal. The brand images of these two latter energy sources would be almost as positive as that of water, solar, geothermal, and wind energy if a solution

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[11] Lita Furby et al., *Public Perception of Electric Power Transmission Lines*, 8 J. of Envtl. Psychol. 19 (1988); Lita Furby et al., *Electric Power Transmission Lines, Property Values and Compensation*, 27 J. of Env. Mgt. 69 (1988); Robin Gregory & Detlof von Winterfeldt, *The Effects of Electromagnetic Fields From Transmission Lines on Public Fears and Property Values*, 48 J. of Envtl. Mgt. 201 (1996); Donald MacGregor et al., *Perception of Risk from Electromagnetic Fields: A Psychometric Evaluation of a Risk-Communication Approach*, 14 Risk Analysis 815 (1994); M. Granger Morgan et al., *Powerline Frequency Electric and Magnetic Fields: A Pilot Study of Risk Perception*, 5 Risk Analysis 139 (1985); Peter M. Wiedeman & Holger Schültz, *The Electromagnetic Fields Risk Issue: Constructing Scenarios on the Further Development of Public Debate in Germany*, 45 European Rev. of Applied Psychol. 35 (1995).

[12] Peter H. Kahn, *Children's Moral and Ecological Reasoning about the Prince William Sound Oil Spill*, 33 Developmental Psychol. 1091 (1997); Timothy Rundmo & Lennart Sjöberg, R*isk Perception by Offshore Oil Personnel Related to Platform Movements*, 18 Risk Analysis 111 (1998).

[13] Paul Slovic, *Perception of Risk*, 236 Sci. 280 (1987); Randall Kleinhesselink & Eugene A. Rosa, *Cognitive Representation of Risk Perceptions: A Comparison of Japan and the United States*, 22 J. of Cross-Cultural Psychol. 11 (1991); Etienne Mullet et al., *The Evaluative Factor of Risk Perception*, 23 J. of Applied Soc. Psychol. 1594 (1993); Ali Siddiq Alhakami & Paul Slovic, *A Psychological Study of the Inverse Relationship between Perceived Risk and Perceived Benefit*, 14 Risk Analysis 1085 (1994).

[14] Etienne Mullet et al., *Risk Perception and Energy Production*, 4 Human & Ecological Risk Assessment 153 (1998).

could be found to the problem of atmospheric emission of carbon monoxide.

Concerning production process aspects, waste products, as well as the transportation and storage of waste, received the highest ratings. This is possibly related to the fact that the vast majority of studies devoted to a specific area or aspect have concerned nuclear waste. In contrast, there was not a very high degree of concern regarding the electrical energy transportation domain.

The Present Study

The present study is a direct extension of the Mullet study. A similar, although more complete, set of items was used. These items related to specific energy domains as well as specific aspects of the energy production process. As in the Mullet study, nine energy sources (covering all currently known energy sources), were considered in this study: Wood and bio-mass, coal, gas, oil, nuclear, water, wind, geothermal, and solar. Also, nine stages in the energy production and utilization process were considered: obtaining raw materials, storage of raw materials, transportation of raw materials, energy production, waste products related to energy production, transportation of energy, transportation of waste products, the storage of waste products, and utilization of energy. Crossover of production phases and energy types resulted in a large number of items (119).

This study differed from the Mullet study in two ways. First, we were interested in the structure of risk perception concerning the energy production process manifested by the participants. In the Mullet study this structure was not studied because of the insufficient number of participants. Authors had to base their comparisons on the prior energy domain x stage of production structure, from which the items were deducted. In contrast, in the present study the structure of risk perception will be extracted by factorial analyses, and all comparisons will be made on the basis of this structure.

In regards to the structure of risk perception concerning energy production, it is difficult to make strong hypotheses. We have, however, a number of precise research questions: (a) What is the nature of the factors needed to account for risk perception regarding energy production?; Is risk perception mainly focused around energy domains (nuclear, coal, wind)?; Is risk perception mainly focused on the stages of processing (extraction of raw material, production, waste management)?; Is risk perception focused both around energy domains and the stages of processing?; and (b) How many factors structure the risk perception?; Are there as many factors as the total number of domains?; Is there a reduced set of factors?; Are these factors orthogonal, positively correlated, or negatively correlated?

Second, we were interested in comparing the risks perceived by people who are exposed in different ways to the major perceived risk (determined based on the risk perception studies): nuclear power. Three subgroups of people were asked to participate in the study: (a) persons currently working in a nuclear power plant, (b) persons not currently working in a nuclear power plant but living close to one, and finally (c) persons not currently working in a nuclear power plant and not living close to one. In line with Sjöberg and Drotz-Sjöberg,[15] participants currently working in a nuclear power plant were expected to perceive nuclear energy production as less risky than participants not currently working in a nuclear power plant.[16] Persons not currently working in a nuclear power plant but living close to one, were expected to perceive nuclear energy production as less risky than persons not currently working in a nuclear power plant and not living close to one.

METHOD

Participants

There were 170 participants in total (thirty-eight men and 132 women) forming three subgroups. The first subgroup was composed of twenty-one persons currently working in a nuclear power plant (sixteen men and six women), as well as living close to the site. The mean age of this subgroup was thirty-three years, ranging from twenty-five years to fifty-two years. Participants in this subgroup were engineers, technicians, and workers. The second subgroup was composed of forty persons who lived close to a nuclear site (eleven men and twenty-nine women), but who have never worked in it. The mean age of this subgroup was twenty-three years, ranging from eighteen years to thirty years. About half of these participants were students, and the other half were currently working in very diverse areas. The third group was composed of 109 persons (eleven men and ninety-eight women) who neither lived close to nor worked in a nuclear power plant. The mean age of this subgroup was twenty-two years, ranging from seventeen years to thirty-five years. About half of these participants were also students, and the other half were working at the time of this study.

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[15] Drotz-Sjoberg, *supra* n. 9.

[16] *See* Mika Kivimäki & Raija Kalimo, *Risk Perception Among Nuclear Plant Personnel: A Survey*, 13 Risk Analysis 421 (1993); Mika Kivimäki et al., *Perceived Nuclear Risk, Organizational Commitment, and Appraisals of Management: A Study of Nuclear Power Plant Personnel*, 15 Risk Analysis 391 (1995).

Material

The material consisted essentially of a 119-item questionnaire covering a wide range of energy sources: wood and bio-mass, coal, gas, oil, nuclear, water, wind, geothermal, and solar. They also addressed every stage in the energy production and distribution process, from the extraction of raw materials to energy utilization. Thus, each item concerned both a type of energy and an aspect of the process. For example, the combination "extraction of raw materials" and "uranium" produced the item: extraction of uranium from open air mines. The combination "transportation of raw materials" and "oil" provided the item: transportation of crude oil by giant tanker. The combination "storage of raw materials" and "water" provided the item: storage of water by weight dams.

Not all combinations were retained; for example, the combination "extraction of raw materials" and "water" could not lead to a realistic item. Some combinations resulted in the production of several items; for instance, coal is commonly transported by rail, road, river, or sea. All four modes of transportation were considered. The various items are shown in Table 2. An 11-point response scale (ranging from 0, not risky, to 10, extremely risky) was displayed opposite to each question.

Procedure

Each subject filled out the questionnaire in the presence of an investigator, to ensure that questions and answers were taken seriously. The questionnaire hardly raised any problems, as the terms used were fully understood by the participants. There were, however, four exceptions for which explanations were requested, namely; bio-mass, photo-electric, thermodynamic, and accumulator. We asked: What is the health and environmental risk associated with each item? The mean time needed by a participant to fill out the questionnaire was about thirty four minutes, although the response times were not limited.

RESULTS

Four mean risk ratings were calculated for each item: one overall mean rating, and a mean rating for each of the three subgroups. The overall mean ratings are shown in Table 2. Overall, the highest ratings (more than seven out of ten) concerned the following items: nuclear power plants' radioactive wastes (8.59), emission of lead due to gasoline combustion (7.51), maritime transportation of nuclear power plants' radioactive wastes (7.46), transportation of nuclear power plants' radioactive substances by road (7.44), transportation of plutonium by road (7.35), transportation of nuclear power plants' radioactive wastes by railroad (7.14), storage of the concentrated uranium in vats (yellow cake) (7.04), and finally transportation of crude oil by tanker (7.02). It is interesting to note that most of these ratings concerned the nuclear energy source, while only two ratings related to oil.

Table 2

Mean Risk Ratings on Health and the Environment Obtained for the 119 Energy Sources Considered. Results of the Factorial Analyses.

			Factors				
Items	*M*	*SD*	I	II	III	IV	V
Transportation of plutonium by road	**7.35**	2.53	**0.86**	0.14	0.02	-0.01	0.07
Transportation of plutonium by railroad	**6.64**	2.53	**0.86**	0.13	0.10	0.04	0.10
Transportation of nuclear power plants' radioactive wastes by road	**7.44**	2.58	**0.84**	0.08	0.09	0.06	-0.01
Electricity production by uranium power plants	**6.53**	2.77	**0.82**	0.25	0.16	0.09	-0.09
Utilization of plutonium as the raw material in nuclear power plants	**6.96**	2.62	**0.82**	0.17	0.11	0.04	0.04
Transportation of nuclear power plants' radioactive wastes by railroad	**7.14**	2.69	**0.82**	0.06	0.12	0.00	0.02
Maritime transportation of uranium	**6.68**	2.69	**0.82**	0.04	0.22	0.07	0.05
Transportation of uranium by railroad	6.44	2.67	**0.78**	0.12	0.09	-0.04	0.08
Transportation of uranium by special road convoys	6.12	2.87	**0.78**	0.06	0.09	0.12	0.07
Maritime transportation of nuclear power plants' radioactive wastes	**7.46**	2.73	**0.76**	0.10	0.29	0.04	-0.03
Plutonium production by the reuse of uranium	**6.88**	2.63	**0.74**	0.08	0.11	0.06	0.07
Nuclear power plants' highly radioactive wastes	**8.59**	2.08	**0.71**	0.11	0.06	0.09	-0.06
Maritime transportation of plutonium	**6.82**	2.61	**0.68**	0.11	0.11	-0.22	0.13
Storage of nuclear power plants' radioactive wastes in concrete-lined pits inside processing plants	6.09	2.70	**0.67**	0.06	0.12	0.14	-0.03

Table 2 (Cont'd.)

			Factors				
Items	*M*	*SD*	I	II	III	IV	V
Storage of nuclear power plants' radioactive wastes in geological formations	**7.47**	2.52	**0.65**	0.08	0.21	0.17	-0.02
Storage of concentrated uranium (yellow cake) in vats	**7.01**	2.50	**0.63**	0.00	0.05	0.05	0.01
Extraction of uranium from open air mines	6.29	2.89	**0.62**	0.05	0.28	0.08	0.05
Extraction of uranium from underground mines	5.86	2.86	**0.62**	0.10	0.28	0.23	0.09
Nuclear power plants' low radioactive wastes	5.96	2.51	**0.57**	0.11	0.17	0.22	0.06
Transportation of power produced by nuclear power plants by industrial high voltage circuits	5.02	2.88	**0.55**	0.19	0.30	**0.37**	-0.13
Wastes produced by extraction of uranium from mines	5.22	3.15	**0.55**	0.16	0.21	0.18	0.18
Transportation of power produced by nuclear power plants by very high voltage circuits	4.96	2.85	**0.53**	0.25	0.23	0.41	-0.10
Electricity production in nuclear power plants (generator type)	6.38	2.54	**0.49**	0.15	0.16	0.11	-0.16
Dumping of the waters from the nuclear power plants' cooling systems into the rivers, lakes and seas	5.59	3.24	**0.42**	0.05	**0.31**	0.25	-0.14
Industrial utilization of very high voltage power produced by nuclear power plants	3.32	2.52	**0.42**	-0.01	**0.41**	**0.39**	-0.06
Transportation of electricity produced by coal power plants by very high voltage circuits	4.61	2.58	**0.39**	0.18	0.27	**0.36**	-0.08
Emission of sulfur monoxide due to coal combustion	6.28	2.17	0.17	**0.76**	0.00	0.11	0.11
Emission of carbon monoxide due to gasoline combustion	**6.68**	2.01	0.14	**0.76**	0.17	0.09	-0.06
Emission of sulfur dioxide due to oil refinement	**6.72**	2.11	0.22	**0.76**	0.09	0.09	0.06
Emission of hydrocarbons due to gasoline combustion	**6.66**	1.95	0.25	**0.68**	0.18	0.07	-0.02
Emission of carbon monoxide by oil power plants	**6.55**	2.28	0.14	**0.67**	0.16	0.01	0.01
Emission of carbon monoxide due to coal combustion	6.32	2.01	0.08	**0.66**	0.04	-0.01	0.04
Emission of nitrogen oxide due to coal combustion	5.66	2.10	0.13	**0.64**	0.14	0.14	0.02
Emission of nitrogen oxide due to gasoline combustion	6.38	2.02	0.24	**0.58**	0.22	0.12	-0.05

Table 2 (Cont'd.)

			Factors				
Items	*M*	*SD*	I	II	III	IV	V
Emission of carbon monoxide due to the conversion of bio-mass	5.06	2.37	0.07	**0.56**	-0.06	0.19	0.16
Emission of carbon monoxide due to wood combustion	4.70	2.27	-0.06	**0.55**	0.00	0.00	**0.33**
Utilization of gasoline in vehicles' engines	4.86	2.38	0.16	**0.55**	0.17	-0.09	0.13
Storage of domestic wastes	4.29	2.49	0.03	**0.53**	0.15	0.00	0.27
Utilization of diesel fuel	4.89	2.51	0.07	**0.53**	**0.31**	-0.04	0.12
Utilization of fuel in vehicles' engines	4.75	2.34	0.11	**0.53**	**0.35**	-0.06	0.05
Emission of lead from gasoline combustion	**7.51**	1.98	0.26	**0.51**	0.16	-0.15	0.03
Oil refinement	5.09	2.16	0.27	**0.47**	0.23	0.14	0.24
Domestic coal heating systems	3.45	2.25	-0.03	**0.47**	**0.40**	0.13	0.14
Electricity production in coal power plants	3.89	2.04	0.05	**0.46**	**0.36**	**0.36**	0.01
Cutting of forests' trees	5.01	3.16	0.02	**0.42**	0.12	0.06	-0.05
Electricity production in oil power plants	4.70	2.03	0.30	**0.40**	**0.38**	0.28	-0.03
Maritime transportation of coal	2.79	2.39	0.14	0.13	**0.68**	0.05	0.28
Transportation of coal by river	2.44	2.10	0.00	0.28	**0.63**	0.07	0.36
Transportation of coal by railroad	2.03	1.81	-0.02	0.08	**0.59**	0.12	0.22
Transportation of power generated by coal power plants by low voltage circuits	3.04	1.93	**0.32**	-0.01	**0.59**	0.35	0.20
Extraction of oil by off-shore drilling	4.64	2.43	**0.31**	-0.01	**0.59**	0.03	0.10
Extraction of coal from open air mines	3.73	2.60	0.08	0.14	**0.58**	0.14	0.28
Maritime transportation of liquid gas	5.06	2.36	**0.37**	0.14	**0.58**	-0.06	0.09
Transportation of gas by underwater pipelines	4.08	2.40	0.23	0.13	**0.58**	0.23	0.06
Storage of gas in the water table	5.13	2.48	0.29	0.11	**0.56**	0.09	-0.07
Storage of coal in cellars or silos	2.60	2.20	-0.05	0.23	**0.55**	0.20	0.19
Electricity production by gas power plants	4.29	2.18	**0.31**	0.22	**0.55**	0.27	-0.03
Transportation of coal by pipelines	3.27	2.23	0.13	0.17	**0.55**	0.20	0.27
Extraction of oil by land drilling	4.54	2.20	**0.31**	0.17	**0.55**	0.23	0.01
Extraction of natural gas by drilling	4.09	2.28	0.18	-0.03	**0.55**	0.17	0.26
Storage of gas in salt layers	4.62	2.31	0.19	0.13	**0.54**	-0.01	0.12
Utilization of power generated by oil power plants	3.85	2.44	**0.38**	0.07	**0.54**	**0.35**	0.03
Storage of gas in underground reservoirs	4.25	2.32	0.27	0.16	**0.53**	0.16	0.05
Transportation of butane or propane bottles by road	4.71	2.50	0.19	0.22	**0.52**	0.08	0.17
Utilization of power produced by coal power plants	3.18	2.10	0.19	0.15	**0.52**	**0.36**	0.15

Table 2 (Cont'd.)

			Factors				
Items	*M*	*SD*	I	II	III	IV	V
Transportation of liquid gas by pipelines	4.03	2.12	0.28	0.30	**0.50**	0.15	0.07
Transportation of crude oil by pipelines	4.51	2.21	0.25	0.23	**0.50**	0.08	0.19
Utilization of gas as fuel for vehicles	4.20	2.77	0.08	0.16	**0.50**	0.15	0.01
Storage of butane or propane in bottles for domestic use	3.15	2.24	0.06	-0.05	**0.50**	0.08	0.17
Transportation of coal by road	2.39	2.04	0.08	0.24	**0.50**	0.14	**0.46**
Transportation of coal by coal pipelines	2.75	2.15	-0.07	0.20	**0.49**	0.24	0.20
Storage of crude oil in vats	4.47	2.30	**0.35**	0.12	**0.49**	0.05	0.21
Utilization of electricity produced by gas power plants	3.71	2.22	**0.32**	0.12	**0.49**	0.28	-0.10
Transportation of nuclear power plants' electricity by low voltage circuits	3.57	2.57	**0.37**	0.02	**0.49**	0.29	0.04
Transportation of fuel by river	5.72	2.45	**0.39**	0.29	**0.45**	-0.13	0.19
Domestic heating systems using electricity produced by nuclear power plants	2.93	2.60	**.031**	0.07	**0.45**	0.30	-0.17
Emission of ashes due to coal combustion	3.88	2.41	-0.06	**0.38**	**0.44**	-0.01	0.25
Domestic heating systems using fuel	3.37	2.13	0.15	0.30	**0.43**	0.03	0.19
Domestic utilization of low voltage power produced by nuclear power plants	2.22	2.31	0.24	0.02	**0.42**	0.35	0.05
Extraction of coal from underground mines	3.93	2.39	0.00	0.24	**0.42**	0.11	**0.41**
Transportation of gasoline by railroad tankers	4.85	2.29	**0.27**	0.17	**0.42**	0.03	**0.35**
Transportation of fuel by tanker trucks	5.24	2.37	**0.38**	0.24	**0.42**	-0.08	**0.32**
Transportation of coal power plants' electricity by very high voltage circuits	3.89	2.37	**0.40**	0.21	**0.45**	**0.33**	-0.04
Storage of refineries' wastes in underground pits made in salt deposits	5.54	2.39	**0.35**	0.30	**0.41**	-0.06	0.18
Transportation of crude oil by tankers	**7.02**	2.45	**0.33**	0.30	**0.41**	-0.17	0.12
Transportation of gas by underground gas pipelines	3.72	2.27	0.22	0.18	**0.41**	0.29	0.02
Storage of refined oil products in city deposits	6.24	2.57	0.02	0.14	**0.41**	0.15	0.11
Transportation of gasoline by tanker trucks	5.23	2.43	0.32	0.26	0.39	0.00	0.21
Electricity production by marine currents	1.76	1.82	0.00	0.06	0.10	**0.78**	0.16

Table 2 (Cont'd.)

			Factors				
Items	*M*	*SD*	I	II	III	IV	V
Electricity production by tidal movement	2.01	1.94	0.03	0.09	0.12	**0.74**	0.16
Electricity production by arch-dams	2.76	1.96	0.17	0.02	0.16	**0.72**	0.10
Domestic heating systems based on eolien electricity	1.34	1.73	-0.07	0.11	0.12	**0.71**	0.26
Electricity production by thermo-dynamic conversion	2.04	1.78	0.13	-0.03	0.21	**0.68**	0.26
Electricity production by weight-dams	3.05	2.15	0.20	0.13	0.10	**0.67**	0.14
Utilization of electricity produced by hydroelectric power plants	2.12	1.90	0.23	0.05	0.20	**0.65**	0.26
Domestic heating systems based on nuclear power plants' electricity	2.22	1.99	0.27	0.05	0.30	**0.61**	0.16
Utilization of electricity produced by eolien sources	0.84	1.36	-0.06	-0.02	0.06	**0.59**	**0.36**
Electricity production by aero-generators	1.09	1.43	-0.11	-0.01	0.06	**0.52**	**0.38**
Utilization of electricity produced by marine energy	1.65	1.75	0.00	0.05	0.24	**0.50**	0.12
Storage of water by arch dams	2.94	2.12	0.10	0.06	-0.03	**0.50**	0.27
Domestic heating systems based on bio-mass	2.42	2.20	0.11	0.11	0.19	**0.47**	0.19
Storage of water by weight-dams	3.61	2.27	0.20	0.10	0.07	**0.44**	0.00
Transportation of tree trunks by river	1.67	1.87	-0.08	0.15	0.20	0.14	**0.66**
Transportation of tree trunks by road	2.18	2.14	-0.01	0.11	0.13	0.26	**0.66**
Transportation of tree trunks by railroad	1.68	1.89	-0.07	0.06	0.28	0.19	**0.60**
Maritime transportation of tree trunks	1.21	1.61	-0.02	0.20	0.16	0.12	**0.60**
Electricity production by solar panels	1.00	1.29	-0.06	-0.07	0.03	**0.46**	**0.59**
Storage of agricultural by-products	2.54	2.21	0.08	0.29	0.08	0.17	**0.53**
Extraction of hot water from hot springs	1.96	1.98	0.13	-0.15	0.14	0.40	**0.51**
Domestic heating systems based on geothermal electricity	1.56	1.62	0.09	-0.14	0.21	**0.50**	**0.50**
Utilization of electricity based on solar power	.79	1.22	-0.01	-0.09	0.09	**0.42**	**0.50**
Transportation of domestic wastes by road	2.67	2.23	0.11	0.24	0.36	-0.08	**0.48**
Storage of tree trunks	1.08	1.69	0.03	0.24	0.04	0.13	**0.46**
Electricity production by photo-voltaic conversion	1.04	1.25	0.03	-0.08	0.17	**0.52**	**0.45**
Worn solar panels	2.84	2.44	0.01	0.02	0.15	0.29	**0.44**

Table 2 (Cont'd.)

			Factors				
Items	*M*	*SD*	I	II	III	IV	V
Domestic heating systems based on solar energy	.54	1.08	-0.08	0.01	0.12	**0.32**	**0.43**
Electricity production by geysers	2.70	2.17	0.19	-0.04	**0.33**	0.30	**0.42**
Electricity production by bio-mass	2.98	2.22	0.04	0.02	0.23	0.23	**0.39**
Utilization of fuel produced by bio-mass	2.74	1.98	0.18	0.06	**0.35**	0.16	**0.38**
Explained Variance			15.94	9.25	13.62	1.03	7.50
Percentage of Explained Variance			0.13	0.08	0.11	0.08	0.06
Weighted Mean			6.11	5.34	3.94	2.64	2.48
Nuclear				0.45	0.62	0.37	0.28
Fossil : Production and Waste					0.60	0.32	0.36
Fossil : Extraction and Transportation						0.54	0.59
Natural : Hydraulic							0.72
Industrial			**0.73**	**0.69**	**0.69**	0.26	0.25
Natural			0.17	0.21	0.47	**0.80**	**0.82**

The lowest ratings were given to the following items: domestic heating systems based on solar energy (0.54), utilization of electricity based on solar power (0.79), utilization of electricity produced by eolien sources (0.84), electricity production by solar panels (1.00), electricity production by photo-voltaic conversion (1.04), storage of tree trunks (1.08), electricity production by aero-generators (1.09), maritime transportation of tree trunks (1.21), and finally domestic heating systems based on eolien electricity (1.34). Our items covered the most traditional material (wood) as well as some of the latest techniques (solar and eoliens).

The overall standard deviations are also shown in Table 2. The highest standard deviations (more than 2.80) found concerned the following items: dumping of the waters from nuclear plants' cooling systems into the rivers, lakes and seas (3.24), wastes produced by extraction of uranium from mines (3.15), extraction of uranium from open air mines (2.89), extraction of uranium from underground mines (2.86), transportation of power from nuclear power plants by industrial high voltage circuits (2.88), transportation of uranium by special road convoys (2.87), and transportation of power from nuclear power plants by very high voltage circuits (2.85).

All of these high values concerned the energy source for which the highest means were found: nuclear. The lowest standard deviations (less than 1.40) found concerned the following items: domestic heating systems based on solar energy (1.08), utilization of electricity produced by solar energy (1.22), electricity production by photo-voltaic conversion (1.25), electricity production by solar panels (1.29), and utilization of electricity produced by eoliens sources(1.36). All of these values concerned the two energy sources for which the lowest means were found: solar and wind.

Factor Analysis

A factor analysis was conducted on the raw data. A five-factor orthogonal solution was first retained; it explained 46% of the variance (when the data from the subgroup working in a nuclear power plant were discarded from the analysis, the factor structure found was essentially the same). The results are given in Table 2.

The first factor, called *Nuclear*, explained 13% of the variance. It was heavily loaded by items like transportation of plutonium by road, transportation of plutonium by railroad, transportation of the nuclear power plants' radioactive wastes by road, electricity production by uranium power plants, utilization of plutonium as the raw material in nuclear power plants, transportation of nuclear power plants' radioactive wastes by railroad, and maritime transportation of uranium.

All the loadings of these items were higher than .80. A mean severity score was computed for the *Nuclear* factor by (a) multiplying the mean severity score of each item by the square of its loading on this factor, (b) summing all the products obtained, and (c) dividing this sum by the sum of the squares of the corresponding loadings. The value observed was 6.11. This value was closer to the scale's very risky pole than to its no risk pole.

The second factor was called *Fossil: Production and Waste*; it explained 8% of the variance. It was highly loaded by items like: emission of sulfur monoxide due to coal combustion, emission of carbon monoxide due to gasoline combustion, emission of sulfur dioxide due to oil refinement, emission of hydrocarbons due to gasoline combustion, emission of carbon monoxide by oil power plants, and emission of carbon monoxide due to coal combustion. The loadings of these items were higher than .65 but lower than .80. The mean severity value computed for the *Fossil: Production and Waste* factor was 5.34; this value was midway between no risks and very risky.

The third factor was called *Fossil: Extraction and Transportation*; it explained 11% of the variance. It was moderately loaded by items like: maritime transportation of coal, transportation of coal by river, transportation of coal by railroad, transportation of power generated by coal power plants by low voltage circuits, extraction of oil by off-shore drilling, extraction of coal from open air mines, maritime transportation of liquid gas, transportation of gas by underwater pipelines, and storage of gas in deep reservoir layer. The loadings of these items were higher than .55 but lower than .70. The mean severity value computed for the *Fossil: Extraction and Transportation* factor was 3.94, notably lower than the value obtained for the *Fossil: Production and Waste* factor.

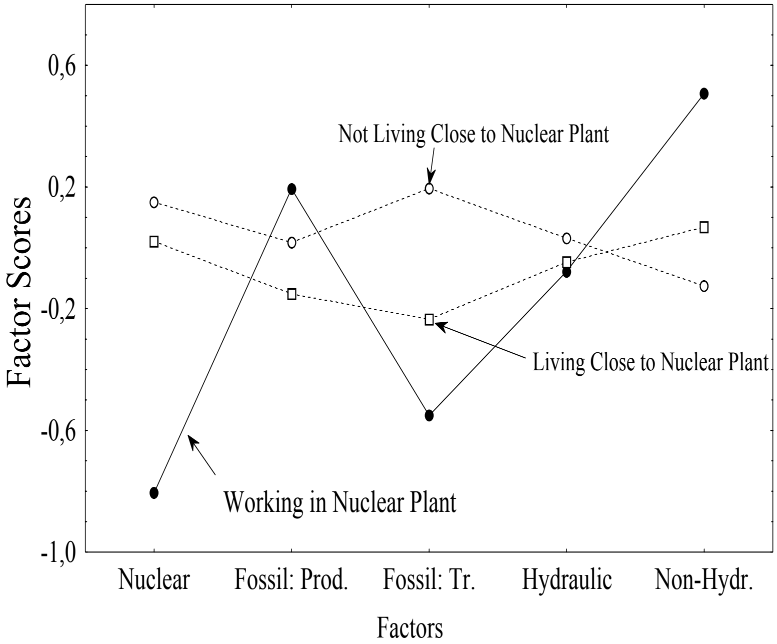
The fourth factor was called *Natural: Hydraulic*; it explained 8% of the variance. It was highly loaded by items like: electricity production by marine currents, electricity production by tidal movements, electricity production by arch-dams, domestic heating systems using eolien electricity, electricity production by thermodynamic conversion, and electricity production by weight dams. The loadings of these items were higher than .65 but lower than .80. The mean severity value computed for the *Hydraulic* factor was 2.64. This value was clearly closer to the scale's no risk pole than to its very risky pole.

Finally, the fifth factor was called *Natural: Non-Hydraulic*; it explained 6% of the variance. It was moderately loaded by items like: transportation of tree trunks by river, transportation of tree trunks by road, transportation of tree trunks by railroad, maritime transportation of tree trunks, electricity production by solar panels, storage of agricultural by-products, extraction of hot water from hot springs, domestic heating systems based on geothermal electricity, and utilization of electricity based on solar power. The loadings of these items were higher than .50 but lower than .70. The mean severity value computed for the *Natural: Non-Hydraulic* factor was 2.48, very close to the one computed for the *Natural: Hydraulic* factor. Substantial correlation coefficients between the five factors were found; they are shown in Table 2. As a result, an oblique five-factor solution was performed. Two higher order factors emerged. The first higher order was called *Industrial*. It correlated strongly with the *Nuclear, Fossil*: *Production and Waste,* and *Fossil: Extraction and Transportation* factors. The second higher order factor was called *Natural.* It correlated strongly with the *Natural: Hydraulic* and *Natural: Non-Hydraulic* factors. An aggregate severity score was computed for each of these two factors by summing the responses obtained for the 11 items with the highest loadings on the two factors. The correlation between the two series of means was +.21 (+.46 in the subgroup of participants working in a nuclear power plant).

Effects of Gender, Age, and Proximity to a Nuclear Power Plant

The five factor scores of each participant were computed, and a series of analyses of variance were conducted with each of these series of scores as dependent variables and the proximity to a Nuclear Power Plant factor as an independent variable. Figure 1 illustrates the main results of these comparisons. A strong effect was observed for the *Nuclear* factor. For participants currently working in a nuclear power plant, the means scores were much lower than for other participants, *F*(1, 168) = 17.01, $p < .00001$. For the seven items quoted above, the mean response given by the participants currently working in a nuclear power plant, was 4.86; for the other participants it was 7.01. The difference was more than 2 points on an 11-point response scale.

Figure 1



A moderate effect was observed for the *Natural: Non-Hydraulic* factor. For participants currently working in a nuclear power plant, mean scores were slightly higher than for other participants, F(1, 168) = 6.42, $p < .02$. Finally, a moderate effect was observed for the *Fossil: Extraction and Transportation* factor. For participants not living close to a nuclear power plant, means scores were slightly higher than for other participants, F(1, 168) = 7.39, $p < .01$.

Subsequent analyses with gender and age as independent variables did not show any significant effect of these factors.

Complementary Analyses

Several items were designed in order to assess how the risk perception on the use of electricity varies according to the source of the energy. Utilization of electricity based on solar power (.79) or utilization of electricity produced by eoliens sources (.84) were perceived as significantly less risky than utilization of electricity produced by marine energy (1.65) and utilization of electricity produced by hydroelectric power plants (2.12), which in turn were perceived as significantly less risky than utilization of power produced by coal power plants (3.18), industrial utilization of high voltage power produced by nuclear power plants (3.32), utilization of electricity produced by gas power plants (3.71) and utilization of electricity produced by oil power plants (3.85). Among participants currently working in a nuclear power plant, however, these differences were much more reduced and non-significant.

DISCUSSION

The present study was aimed: (a) at examining the structure of risk perception as regards to energy production manifested by a set of diverse participants, and (b) at comparing the risk perception of people who are differently exposed to the major perceived risk deducted from every risk perception study: nuclear power.

Concerning the structure of the perception of risk, our first question was: What is the nature of the factors needed to account for risk perception regarding energy production? It was shown that the structure of risk perception as regards to energy production was mainly organized around energy domains. The main domains concerned were nuclear, fossil (coal, oil and gas), hydraulic (rivers and seas), and natural (wood, bio-mass, wind, solar). The *Nuclear* domain and the *Fossil* domain were perceived as posing notably higher risk than the *Natural* domains. The higher risks in the nuclear domain were associated with waste products' transportation and storage (about 7.50 out of 10). The higher risks in the fossil domain were associated with the diverse emissions linked to combustion (lead, carbon monoxide, sulfur monoxide), and to the transportation of crude oil, especially by sea (about 7.00). The higher risks in the natural hydraulic domain were associated with the storage of water in dams (about 3.00). Finally, the higher risks in the natural, non-hydraulic domain were associated with electricity production from bio-mass, worn solar panels and utilization of environment friendly fuel (about 2.75). The results regarding the hierarchy of severity ratings among the four domains are consistent with the results previously found in the Mullet study.[17]

It was also shown that the structure of risk perception as regards to energy production was organized around stages of processing for the diverse

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[17] *See supra* n. 14.

fossil energies considered (production and waste versus extraction, transportation, and storage). The production and waste stages were perceived as posing a higher risk than the extraction, transportation and storage stages.

With regard to the structure of the perception of risk, our second question was: How many factors structure the risk perception? A five-factor structure was found the more adequate structure to account for the data. In addition, this structure was shown as not being an orthogonal one; a two-factor super structure was evidenced. Interestingly, these two super-factors, called *Industrial* and *Natural,* were themselves slightly positively correlated. Contrary to what could have been guessed, the participants who see more risks in nuclear energy production or in the use of fossil energy, also tended to see more risks in solar or hydraulic energy production.

The obtained structure appeared notably different from the three-factor structure identified in Slovic, Fischhoff and Lichtenstein,[18] or from the four-factor structure identified in the Mullet study.[19] In the present study, risk perception appeared clearly organized as a function of the kind of hazard. The reason for these differences has to be found in the analyzed database. In Slovic, Fischhoff and Lichtenstein[20] or in the Mullet study,[21] participants were asked to rate a number of hazards as a function of their aspects: catastrophic, new, voluntary, or known to science. Data were aggregated across participants and the database analyzed was an Aspect x Hazard matrix. The identified three or four-factor structure reflected the way the various aspects structured themselves as a function of the hazards, considered and from the viewpoint of the average participant. In the present study, as indicated in the results section, a Hazard x Participants data matrix was analyzed. The identified five-factor structure reflects the way the various hazards structure themselves from the viewpoint of the individual participants. The two types of structures do not need to be identical; they correspond to complementary viewpoints as regards to risk perception. In the present study, a Hazard x Participants data matrix was used because individual scores were needed.

As regards to the difference in risk perception among people differently exposed to nuclear power production, participants working in a nuclear power plant were expected to perceive nuclear energy production as a less risky prospect than participants not working in a nuclear power plant. This was confirmed. Our results were consistent with Kivimäki and Ka-

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[18] *See supra* n. 2.

[19] Mullet, *supra* n. 13.

[20] *See supra* n. 2.

[21] Mullet, *supra* n. 13.

limo[22] and Kivimäki, Kalimo and Salminen.[23] Additionally, participants working in a nuclear power plant were shown to perceive solar and traditional energy production as a more risky prospect than participants not working in a nuclear power plant.

Also, the participants not working in a nuclear power plant but living close to one were expected to perceive nuclear energy production as a less risky prospect than individuals not working in a nuclear power plant and not living close to one: this was not confirmed. The differences between these two subgroups were minimal and only concerned the extraction and transportation of fossil material (coal and oil).

Limitation

This study has an important limitation that resides in the way the sample was constituted. Participants were volunteers, and although special efforts were made to contact people from different geographic areas and from different educational levels, we are unsure about the representativeness of our sample. As a result, the value of the present study is not in precisely estimating the risk level perceived for each hazard in the French populations, but in adding evidence on the way risk perception regarding energy production is structured and on the way various personal and social characteristics impact on this structure.

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[22] *See supra* n. 16.

[23] *See* Kivimäki et al, *supra* n. 16.